Implementation of an S-Band Microwave Link for Spacecraft Compatibility Testing

R. Sniffin
DSIF Engineering Section

As a cost-effective and time-effective approach to spacecraft compatibility testing, a microwave link between the Jet Propulsion Laboratory and TRW, Inc., has been installed, and the performance of this link has been evaluated experimentally.

I. Introduction

The Deep Space Network requires that all spacecraft which are to be tracked by its stations receive a compatibility test prior to launch. Two facilities are maintained for this purpose. One of these, DSS 71, is located at Cape Kennedy and is used for pre-launch checkout of the spacecraft. The second facility, CTA 21, is located at the Jet Propulsion Laboratory in Pasadena, California and is used for engineering checkout of spacecraft and spacecraft subsystems before shipment to the launch facility.

The *Pioneers F* and *G* spacecraft scheduled for launch in March of 1972 and April of 1973 are being designed and constructed for the Ames Research Center by TRW Systems Division of Redondo Beach, California. As a practical alternative to requiring the Pioneer Project to supply a spacecraft to the DSN for testing at CTA 21, it was decided to conduct as many tests as possible using a microwave link between CTA 21 and TRW. The remaining tests would either be performed at CTA 21 on spacecraft subsystems or at DSS 71 on the flight spacecraft. The decision as to which tests could be conducted via the microwave link would be based on the performance of the link.

II. Path Selection

The Jet Propulsion Laboratory lies against the foothills of the San Gabriel Mountains 39 km north, northeast of TRW. Between the two facilities are a group of low mountains called the San Rafael Hills. These hills preclude any single-hop microwave link. It is also doubtful that a single-hop link would be successful due to the low grazing angle of the beam with the terrain and the resulting interference from man-made structures. It is therefore both necessary and desirable to use a passive repeater located on an intervening terrain peak. There are three peaks in the San Rafael Hills from which line-of-sight transmission to both JPL and TRW are possible. One of these, however, was eliminated due to a JPL building which partially blocks the path from the JPL microwave relay antenna complex. The choice between the remaining two peaks was made on the basis of the ease with which a permit for use of the land could be obtained and the ease with which the antennas could be installed.

The selected location was on an abandoned fire lookout tower owned by the County of Los Angeles. Figure 1 shows the terrain profile along the two portions of the link. A helicopter survey was also made to ensure that no man-made obstructions were present. The line between the terrain and the line-of-sight path represents the boundary of the first Fresnel zone. This zone is normally considered to be the region which must be free of obstructions in order to have free-space propagation conditions apply. Since a considerable amount of terrain lies within the first Fresnel zone, no attempt was made to calculate the effect of this terrain on the performance of the link.

III. Preliminary Performance Predictions

In order to determine the adequacy of the proposed link hardware, a power study was performed based on free-space propagation conditions. Since these conditions are not realized, the predicted link loss only represents an engineering approximation. Table 1 summarizes the items in terms of their contribution to the total link loss.

IV. Link Stability Test Description

The completed microwave link was tested over a 24-h period extending from 04:02 GMT on February 20, 1971 to 04:02 GMT on February 21, 1971. A modified *Mariner C* flight transponder was used to simulate the spacecraft at the TRW end of the link. Analog (strip-chart) recordings of received signal amplitude and phase at CTA 21 were generated. In addition the receiver automatic gain control voltage was sampled at 0.125-s intervals and recorded on digital tape for later data reduction.

V. Link Stability Test Results

Seventeen hours of signal amplitude data were reduced by an XDS-920 computer. The remaining 7 h could not be reduced by this technique because of tape changes falling within the hour and a partial failure of the transponder. Figure 2 shows the distribution of signal amplitudes (histogram) with the mean and standard deviation of the signal level for each of the seventeen hours which were reduced. Three hours of data were converted to the frequency domain by use of the Cooley-Tukey Fast Fourier Transform. The resultant power spectrums are shown in Fig. 3.

A study of the analog recording of received signal phase showed a diurnal phase change of 158 deg at the received frequency. The phase jitter was less than 5 deg.

VI. Conclusions

The S-band microwave link established between JPL and TRW is usable for large signal testing of the *Pioneer F* and *Pioneer G* telecommunications subsystem. The amplitude stability of the link is nominally ± 1.3 dB.

The signal amplitude stability degrades during the afternoon hours with the largest variations being observed near local sunset. All sidebands caused by varying link amplitude are at least 30 dB below the carrier level. The phase stability of the two-way link is also acceptable for such testing.

Table 1. Microwave link power study

Item	Loss contribution, dB
Cable loss (CTA 21 to antenna)	−5.0
Antenna gain (1.8-m antenna)	+30.0
Propagation loss (3.7 km at 2295 MHz)	−111.1
Antenna gain (1.8-m antenna)	+30.0
Cable loss (10.5-m type T-214)	−4.3
Antenna gain (1.8-m antenna)	+30.0
Propagation loss (35.7 km at 2295 MHz)	−131.7
Antenna gain (1.8-m antenna)	+30.0
Cable loss (to measurement point)	−2.6
Total microwave link loss	−134.7

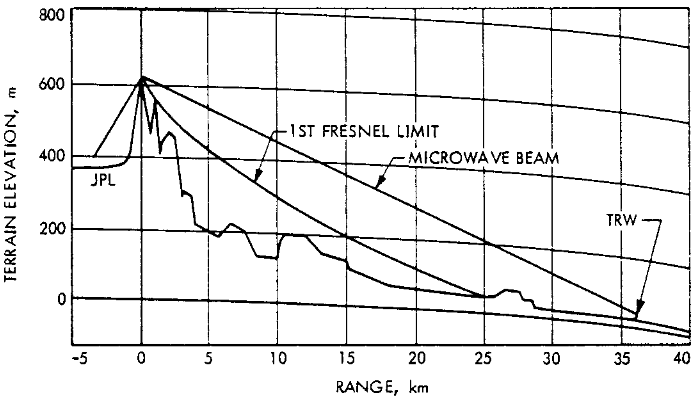

Fig. 1. Terrain profile and first Fresnel zone limit

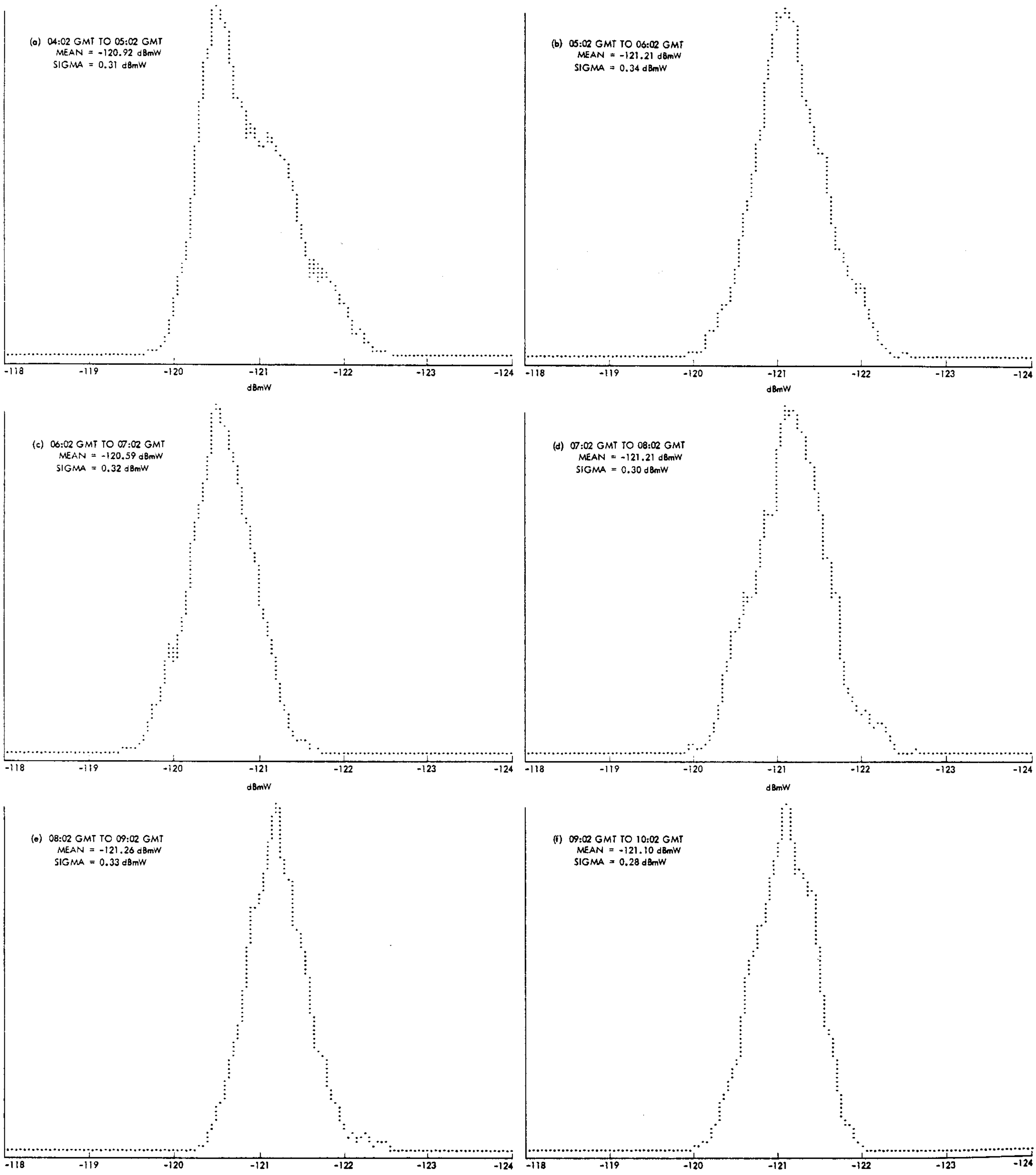

Fig. 2. Distribution of signal amplitudes

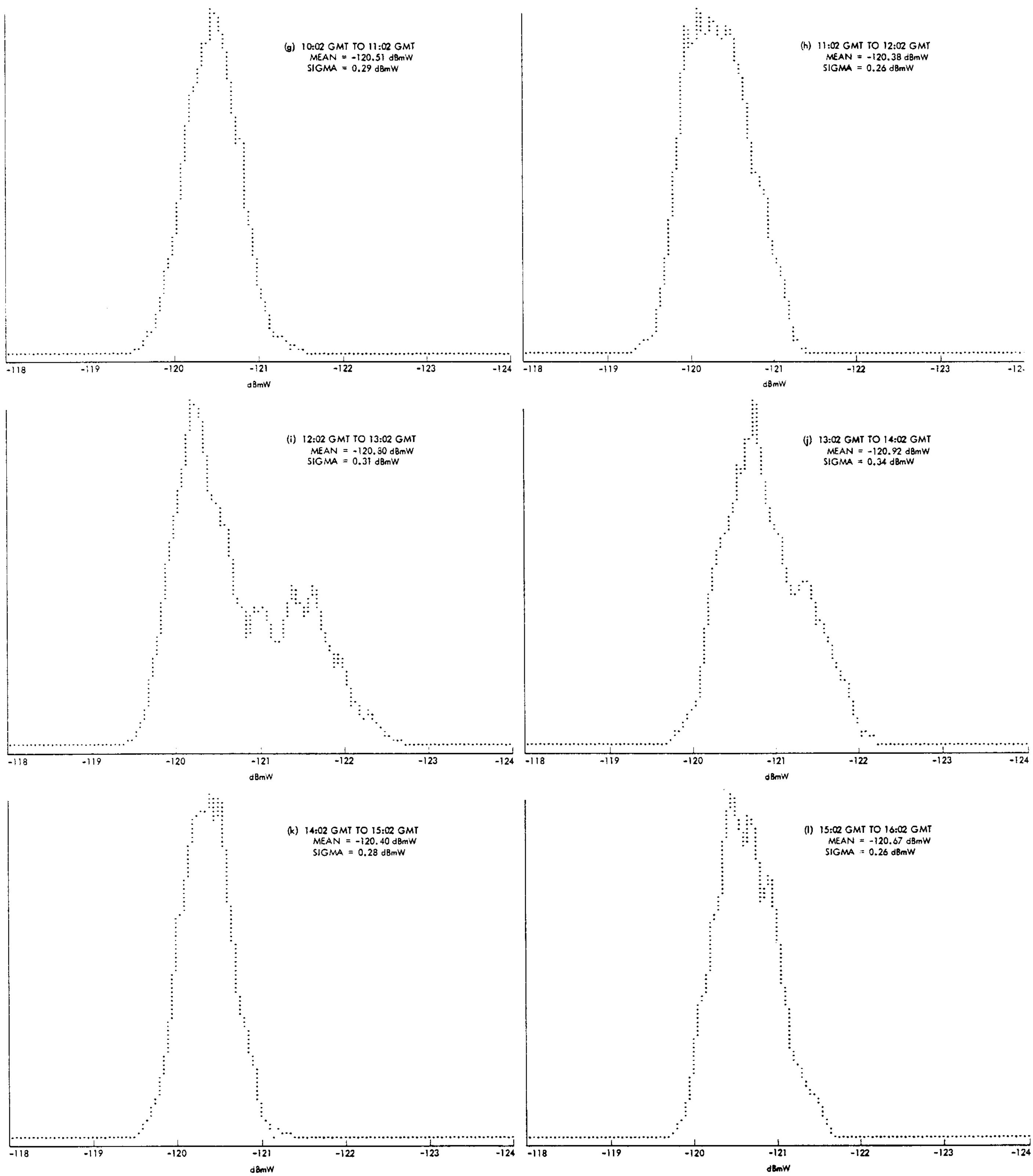
(g) 10:02 GMT TO 11:02 GMT
MEAN = -120.51 dBmW
SIGMA = 0.29 dBmW
-118 -119 -120 -121 -122 -123 -124
dBmW
(h) 11:02 GMT TO 12:02 GMT
MEAN = -120.38 dBmW
SIGMA = 0.26 dBmW
-118 -119 -120 -121 -122 -123
dBmW
(i) 12:02 GMT TO 13:02 GMT
MEAN = -120.80 dBmW
SIGMA = 0.31 dBmW
-118 -119 -120 -121 -122 -123 -124
dBmW
(j) 13:02 GMT TO 14:02 GMT
MEAN = -120.92 dBmW
SIGMA = 0.34 dBmW
-118 -119 -120 -121 -122 -123 -124
dBmW
(k) 14:02 GMT TO 15:02 GMT
MEAN = -120.40 dBmW
SIGMA = 0.28 dBmW
-118 -119 -120 -121 -122 -123 -124
dBmW
(l) 15:02 GMT TO 16:02 GMT
MEAN = -120.67 dBmW
SIGMA = 0.26 dBmW
-118 -119 -120 -121 -122 -123 -124
dBmW

Fig. 2. (Contd)

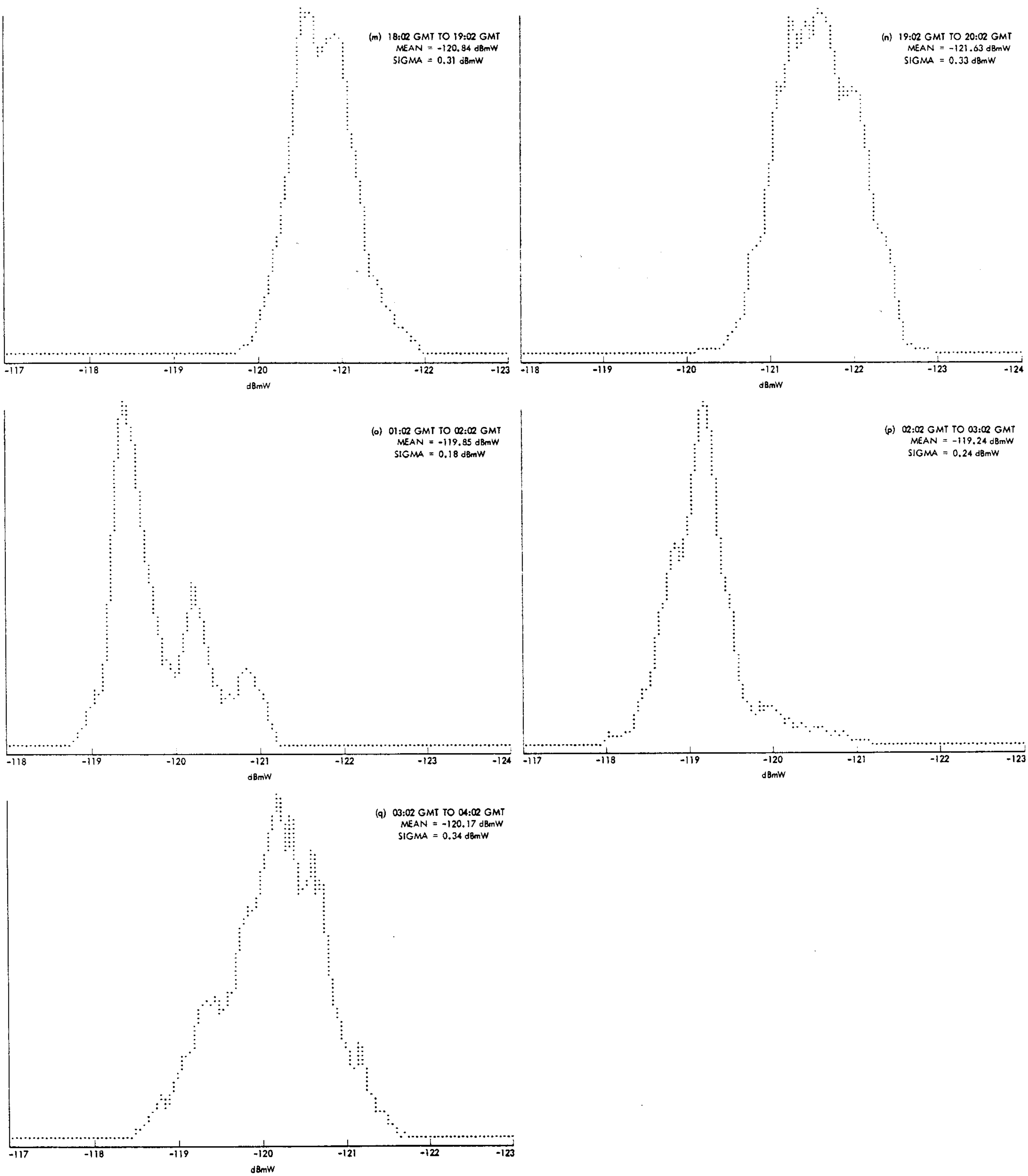
(m) 18:02 GMT TO 19:02 GMT
MEAN = -120.84 dBmW
SIGMA = 0.31 dBmW
-117 -118 -119 -120 -121 -122 -123
dBmW
(n) 19:02 GMT TO 20:02 GMT
MEAN = -121.63 dBmW
SIGMA = 0.33 dBmW
-118 -119 -120 -121 -122 -123 -124
dBmW
(o) 01:02 GMT TO 02:02 GMT
MEAN = -119.85 dBmW
SIGMA = 0.18 dBmW
-118 -119 -120 -121 -122 -123 -124
dBmW
(p) 02:02 GMT TO 03:02 GMT
MEAN = -119.24 dBmW
SIGMA = 0.24 dBmW
-117 -118 -119 -120 -121 -122 -123
dBmW
(q) 03:02 GMT TO 04:02 GMT
MEAN = -120.17 dBmW
SIGMA = 0.34 dBmW
-117 -118 -119 -120 -121 -122 -123
dBmW

Fig. 2. (Contd)

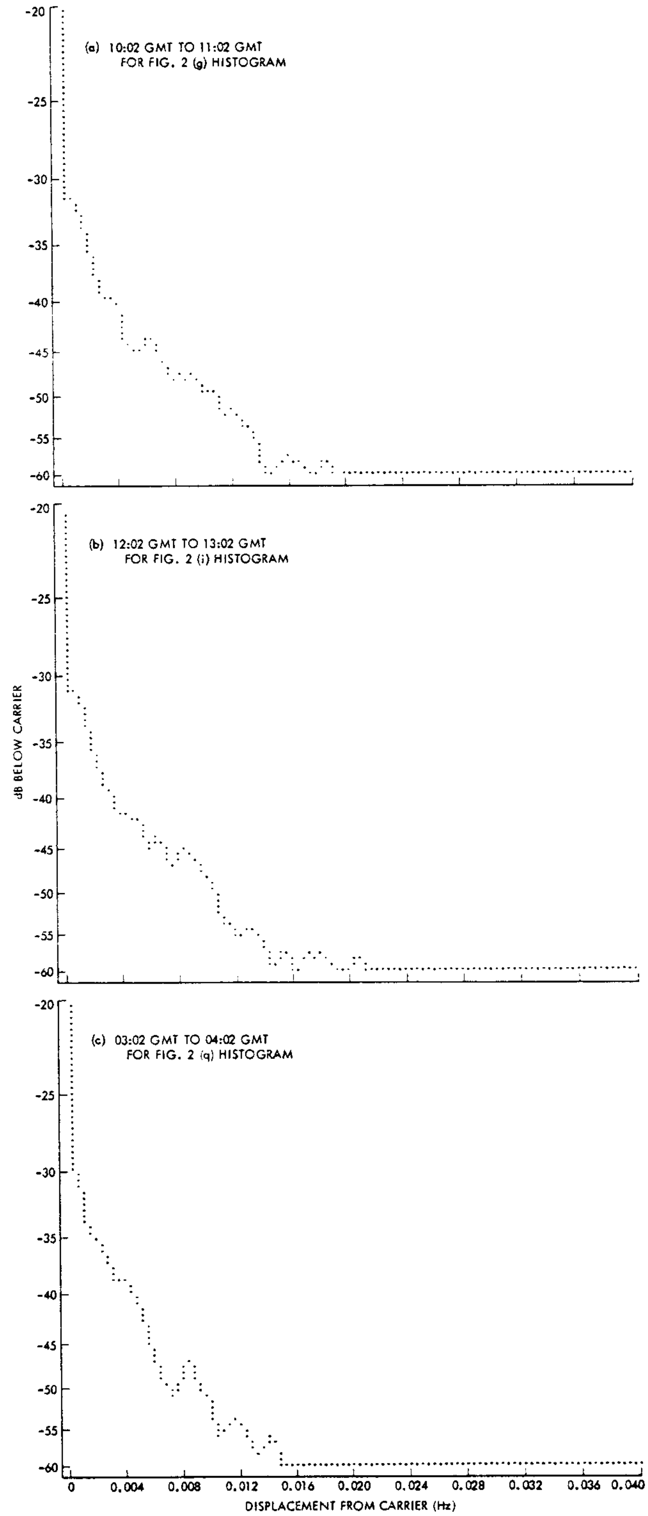

Fig. 3. Power spectrum of received signals